Title: Impact of the Adapted Yam Minisett Technique on ware yam (*Dioscorea rotundata*)
production under farmer-managed conditions in Nigeria

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Abstract

White yam (*Dioscorea rotundata*) is a major root crop grown throughout West Africa and a major limitation on its production is the availability of good quality (i.e. free of pests and diseases) planting material; notably seed yams. One of the methods developed to address this limitation is the Adapted Yam Minisett Technique (AYMT) and since 2012 the AYMT has been promoted in both Nigeria and Ghana via a Bill and Melinda Gates funded project entitled Yam Improvement for Income and Food Security in West Africa (YIIFSWA).

AYMT is a process by which farmers can produce good quality seed yams using setts treated with a pesticide dip. While previously published studies have focussed on the agronomy of the sett-to-seed yam process there has been no work done on the seed-to-ware yam stage which is critical in terms of income and livelihood for yam farmers throughout West Africa. This paper addresses this significant gap in knowledge and provides the first published evidence obtained under entirely farmer-managed conditions in Africa that shows seed yams produced via the AYMT can generate significant agronomic benefits, including better germination, tuber numbers and tuber weights, for ware yam growers in Nigeria.

Keywords: Yam (*Dioscorea rotundata*), adapted yam minisett technique, food security, Nigeria

Introduction

White yam (*Dioscorea rotundata*) is an important root crop for both household income and food security throughout West Africa, but especially in Nigeria, Ghana and Côte d'Ivoire (Onwueme and Charles, 1994; Asiedu and Sartie, 2010). West Africa accounts for some 95% of the global production of white yam (48 million tonnes), and Nigeria produces three quarters of the yams in West Africa (Shehu et al., 2010). There are many cultivated varieties of white yam and this provides farmers with flexibility (Baco et al., 2008) although there is also evidence that diversity is declining as farmers opt for varieties that best suit their local growing conditions and markets (Zannou et al., 2004). There is much potential for improvement in yam via plant breeding (Ekanayakea and Asiedu, 2003), and there have been attempts to produce improved varieties of white yam (Scarcelli et al., 2006) although to date these are not widely available and planted by yam farmers in West Africa. Indeed despite its importance in West Africa the broad agreement amongst farmers and researchers is that the crop has received nothing like the attention it should from policy makers and funders (Shehu et al, 2010). While government help for yam farmers has often revolved around more generic interventions such as the provision of cheap credit and subsidised fertilizer, pesticides and machinery (Agbaje et al., 2005) this may not be sustainable as availability is often poor or non-existent (Oladeji and Oyesola, 2006).

One of the central limitations to yam production which has received some attention from researchers is the availability of good quality planting material, primarily seed yams (Okoli, and Akoroda, 1995; Ekanayakea and Asiedu, 2003; Morse et al., 2009; Mignouna et al., 2014). These can be very expensive (Morse et al, 2009; Korada et al., 2010; McNamara et al, 2012), largely because yam tubers are easily damaged and susceptible to attack from a range

of pests and diseases, including nematodes, which continue throughout the cultivation, storage and marketing cycle (Korada et al., 2010). The pest and disease problems within planting material have proven to be difficult to address, partly because of the wide range of organisms involved and their persistence through the cultivation, storage and marketing periods (Aboagye-Nuamah et al., 2005; Coyne et al., 2006). A number of surveys in Nigeria have explored their perceived limits to ware yam production and availability of seed yam often emerges directly or indirectly, for example as part of a high cost of production, as an important factor (Izekor and Olumese, 2010; Ugwumba and Omojola, 2012).

Various techniques have been developed by both farmers and researchers to try and address this limitation of quality planting material, and many of them are based upon the cutting of healthy ware yam tubers (mother yams) of medium size (~1 kg) into minisetts of various sizes before treating with pesticides and planting. One of these is the Adapted Yam Minisett Technique (AYMT) developed via a series of UK Department for International Development (DFID) funded research projects in the early years of this century (Morse et al., 2009; Coyne et al., 2010; McNamara et al., 2012; Morse and McNamara, 2014). AYMT employs a sett size between 80 and 120g, although farmers are encouraged to experiment with the best sett size under their local circumstances. In general terms the larger the sett size then the larger the size of the resulting yam tubers (George, 1990). The setts are treated with a pesticide ‘dip’ before drying and planting directly into the field. This is a critical stage as without such treatment the yam setts are highly vulnerable to attack from pests and diseases.

Since 2012 the AYMT has been promoted in both Nigeria and Ghana via a Bill and Melinda Gates funded project called Yam Improvement for Income and Food Security in West Africa (YIIFSWA), and some of the agronomic (germination count, average tuber numbers and

weights) and economic results obtained from a series of demonstrations established in 2012 and 2013 were presented in Morse and McNamara (2014). The demonstrations were entirely farmer-managed and farmers were encouraged to use a yam variety of their choice. In the Morse and McNamara (2014) paper emphasis was placed on the differences obtained via the use of the pesticide cocktail relative to untreated controls and also, using data from 2013, the differences between two popular yam varieties (Ekpe and Opoko) and the interaction between yam variety and treatment. The results suggested that the use of the pesticide mixture resulted better survival of setts and larger tubers, indeed some of them approached 1 kg in size, but this is seen as a positive as it provides tubers of ware yam size that can be consumed. Thus the AYMT provides both clean seed yams as well as tubers that can be consumed. There was also a varietal effect evident with regard to the two yam varieties included in the demonstrations, including a significant interaction between variety and pesticide treatment. However an important limitation of the results presented in Morse and McNamara (2014) is that they only refer to the production of seed yams (i.e. sett-to-seed yam). The next logical step, of course, is to see whether the seed yams produced from treated setts do go on to produce better ware yams as shown in Figure 1 (i.e. seed-to-ware yam). After all, there would seem to be little point in producing better quality seed yams if they do not result in benefits for ware yam production. Yet, and perhaps surprisingly, this has not been explored empirically in any depth under farmer-managed conditions in Africa and for the most part the evidence for a correlation between seed quality and ware yam production is based on data from farmer surveys (see, for example, Ibana et al., 2009, 2012).

<Figure 1 near here>

This paper presents the results of YIIFSWA demonstrations designed to use the seed yams produced in 2013 from both treated and untreated setts for ware yam production. It provides the first field evidence of the agronomic impact of growing seed yams produced via AYMT under entirely farmer-managed conditions. The paper presented here has two parts. It will first update the sett-to-seed yam results presented in Morse and McNamara (2014) by including data from the 2014 season. While this part of the paper is admittedly somewhat incremental it will serve to summarise the main findings of the sett-to-seed yam demonstrations. The second, and main, part of the paper will present the results of the seed-to-ware yam demonstrations established in 2014 using seed yams produced via AYMT in the 2013 demonstrations.

Methodology

(a) Sett-to-seed yam demonstrations.

The methodology for the 2014 sett-to-seed yam demonstrations is essentially the same as presented in Morse and McNamara (2014) and need only be summarised here. The YIIFSWA project in 2014 involved a number of different types of demonstration plot established in a number of states in Nigeria. These are:

1. Kogi State: Mostly the area surrounding the town of Idah, on the eastern bank of the River Niger
2. Benue State: Mostly around the villages of Amoke and Agagbe
3. Edo State: The village of Illushi, a major seed yam supplying centre on the western bank of the River Niger
4. Federal Capital Territory: Various locations in the FCT

The number of different types of site and their locations are shown in Table 1. Most of the sites were managed by men, but it is noteworthy that women managed a number of the sites. While yam is regarded as essentially a crop cultivated by men this is not always the case. All plots were entirely farmer-managed, and thus they made the decisions over timing of activities, plant spacing etc.

<Table 1 near here>

The majority of demonstrations established in 2014 were of the sett-to-seed type, and here it is only necessary to describe the 'core' and 'entrepreneur' types established in the Idah area as these are the ones that provided the data for analysis. As in previous years (2012 and 2013), record keeping in the Idah area was much better than in the others and hence there is greater confidence in the quality of the agronomic data. As in previous years, the Idah farmers opted for two varieties - 'Ekpe' and 'Opoko'. Opoko is a relative 'soft' tuber that is easily pounded and described by them as 'sweet' (i.e. has a good taste). Ekpe on the other hand has a tougher tuber that is not as easily to pound as Opoko but is regarded by farmers as being high yielding.

Treatment of the setts was via the 'pesticide dip' method set out in detail in Morse and McNamara (2014). The pesticides employed were Act Force Gold (insecticide; 45% w/w chlorpyrifos) and Z Force (fungicide; 80% w/w mancozeb) and for every 10 litres of water a total of 100 ml of Act Force Gold and 100 g of Z-Force were added. Setts were cut to the recommended size (80 to 120 g) and immersed into the pesticide solution for 5 minutes or so before drying in the shade and planting.

As in 2012 and 2013, a record was kept of plant population, germination, number and weight of seeds harvested per sett planted and germinated. Planting typically takes place between March and May of each year using approximately a one metre spacing between ridges/rows of heaps. The heaps for seed yam production tend to be smaller than those for ware yam, and the within row spacing also tends to be smaller. Seed yams for ware yam production are typically planted at a one metre spacing within each row (equates to approximately one plant per square metre) while setts for seed yam tend to be planted at a spacing which varies between 25cm and 50cm within each row (2 to 4 setts per square metre). Harvesting of seed yam takes place at much the same time as for ware yam; typically between October of the same year and February the following year.

The 2014 core demonstration sites in the Idah area were approximately 20m by 20m in size. Five of the rows (approximately 5m X 20m) were planted with untreated setts while 15 rows (approximately 15m X 20m) were planted with treated setts. Many of the 30 farmers involved in the Idah core sites of 2014 had also been involved in demonstrations in 2012 and 2013 and thus were familiar with the AYMT.

The 2014 entrepreneur sites in Idah comprised plots of 20m by 20m but only one row (approximately 1m X 20m) was planted to untreated setts. The rest of the site (approximately 19m X 20m) was planted to treated setts. The reason for this is that the primary emphasis with the entrepreneur sites is on their economic performance and farmers are understandably anxious to maximise their financial return from the investment of land and labour. Most of the entrepreneurs were the same as those of 2012 and 2013, and thus were also familiar with AYMT.

(b) Seed to ware yam demonstrations

Farmers involved in the 2013 demonstrations were asked to keep some of the seed yam produced from both treated and untreated plots and plant them in adjacent plots in 2014. These demonstrations (30 in number; Table 1) were also farmer-managed with the proviso that no further pesticide was applied to any of the seed yams before planting. Planting for ware yam production tends to take place earlier in the growing season than for seed yam production, but harvesting takes place at much the same time. Demonstrations sizes varied somewhat between farmers and were not as standardised as for the core demonstrations of sett-to-seed. The plot sizes and number of seed yams planted for the 30 sites are summarised as Table 2.

<Table 2 near here>

Selection of seed yams to plant was made by the farmer and the tuber sizes were generally within the typical range for seed yams. It was not possible to record the weights of seed yams planted or indeed their quality in the two parts of each demonstration plot.

The seed-to-ware yam demonstrations had not been attempted in the previous years of the YIIFSWA project and hence were a relatively new enterprise for the farmers, even if they had been involved in the sett-to-seed yam demonstrations. Unfortunately of the 30 demonstrations the yield results from three of them were not usable as the farmers mixed up some of the outputs between treated and untreated plots. Hence it was decided to eliminate the yield data from these demonstrations and the sample size was reduced to 27.

(c) Analysis

As in Morse and McNamara (2014) analysis of the data was primarily via analysis of variance (General Linear Model), with variety and treatment as the main effects.

Results

(a) Sett to seed yam

Figures 2 and 3 show the results of the sett-to-seed yam demonstrations established in 2014 for the Idah area. The bars are for untreated (light colour) and treated (darker colour) plots, and the error bars are the standard errors based upon the error mean square of an analysis of variance. Treated setts germinated better than the untreated and as in 2013 there was no apparent difference between the two varieties Opoko and Ekpe in terms of germination rate. As in 2012 and 2013 the difference between the average tuber weight of seed yams from treated and treated setts was statistically significant, with tubers produced from treated setts having a higher average weight than untreated ones. However, in 2014 the average weight for tubers from treated setts was higher than in previous years; 0.78 to 0.88 kg. This contrasts with comparable figures of approximately 0.6 kg in 2013. These are, of course, averages but even so an average tuber size of between 0.78 to 0.88 kg is closer to the typical size (>1 kg) for a ware rather than a seed yam.

<Figures 2 and 3 near here>

Figure 3 provides the number of tubers harvested and the average tuber weight per sett planted and germinated. The number of tubers harvested per sett planted was higher for treated setts, largely reflecting the better germination rate of treated setts, but in terms of the number of tubers per sett germinated there was no statistically significant (at $P < 0.05$) difference between treated and untreated setts. In terms of average tuber weight per sett planted and germinated this was significantly higher for treated setts in both cases. Thus the pesticide treatment had the effect of aiding sett survival and also boosting the weights of seed yams produced per germinated sett. It is noteworthy that varietal differences were not as marked in the 2014 results as they were in 2013, probably because the sample size (number of demonstrations) was smaller. There were hints of a varietal difference in terms of seed weight per sett planted and germinated but the results were not statistically significant. Unfortunately no assessment of pest/disease levels or tuber quality was possible within the logistical context of the demonstrations so it is not possible to say whether the increased yield also resulted in better quality tubers.

(b) Seed to ware yam

The results of the seed yam demonstrations are shown in Figures 4 and 5. In Figure 4 it is apparent that planting seed yams produced from treated setts improved both the germination rate (73% for untreated and 98% for treated) and average tuber weight (0.6 kg for untreated and 1.2 kg for treated) relative to the use of seed yams from untreated setts. There was also a significant varietal effect as ware yams from Ekpe seeds had a tuber weight higher, on average, than those for Opoko. The benefits in terms of germination and average tuber weight were indeed quite marked and suggest that the benefits from using sett treatment do carry over into ware yam production.

<Figures 4 and 5 near here>

In terms of tuber count and weights on a per seed planted and germinated basis (Figure 5) the results also suggest clear benefits from using seed yams produced from treated setts. The number of ware yam tubers per seed planted was greater for those seeds that were produced by treated setts, and was largely a reflection of the better germination rate for those seeds. The latter was reinforced by the results which suggest that the number of tubers per seed germinated was much the same for seeds from treated and untreated setts. In terms of the weight of tubers per seed planted and germinated it is clear that these were significantly higher for yams grown from seeds produced from treated setts. Indeed the results suggest that using seed yams produced from treated setts can double the size of ware yam tubers. Also of note is the varietal effect as it would appear that Ekpe produces larger tubers than Opoko, although farmers in the Idah area will often tell you this.

Discussion

The sett-to-seed yam demonstrations of 2014 generated findings that are largely in line with those of 2012 and 2013 (Morse and McNamara, 2014). Pesticide treatment helped with sett survival and also resulted in larger seed yams. While no data were recorded for pest and disease incidence it would seem logical to assume that the pesticide provided benefits in terms of reducing these within the setts as well as protection against further infestation once planted. It is of interest that even without the use of pesticide dip treatment the setts were still able to produce a reasonable number of tubers at an average weight that was, if anything, more ideal for seed yams than that obtained from treated setts. The smaller number of

demonstrations in 2014 helps explain most of the differences with the 2012 and 2013 findings, most notably the absence of a statistically significant (at $P < 0.05$) varietal effect for some of the variables. Hence while the results presented here for the sett-to-seed yam demonstrations in 2014 are arguably incremental they do help to reinforce the main benefits of the pesticide dip treatment for setts in the AYMT. As concluded in Morse and McNamara (2014) the AYMT is clearly a technology that can 'work' under entirely farmer-managed conditions.

The major novel insights from 2014 were provided by the seed-to-ware yam demonstrations; the first of their type established in Africa. The planting of seed yams produced by treated setts had a significant positive impact in terms of germination (and hence number of tubers harvested) and tuber weight assessed on a per plant basis. This was already well known from informal discussions with farmers since the AYMT was first introduced into the Idah area. Anecdotal evidence has existed for many years that farmers are well aware of the benefits of growing better quality seed yam and indeed that is why such tubers fetch a greater market price (Ibana et al., 2009, 2012), but the results presented here provide the first empirical field evidence that under farmer-managed conditions the AYMT can ultimately enhance the production of ware yams by farmers. This is an exciting and highly important conclusion as it is ware yam production that the vast majority of farmers are most interested in for both food security and marketing, and availability of good quality planting material at a reasonable price is an often stated limitation (Izekor and Olumese, 2010; Ugwumba and Omojola, 2012). Some farmers do specialise in seed yam production which they supply to ware yam growers (Morse et al., 2009; McNamara et al., 2012), but it is critical to note that improving the quality of seed yam is not an end in itself. The 'better' seed yams must have a positive impact for ware yam production otherwise farmers will not go to the trouble, and indeed expense, of

growing or buying better quality seed yams. It is also important to explore all of this under farmer-managed conditions so as to closely mirror the circumstances within which farmers work.

It is a challenge to separate out the causes of the better performance of seed yams produced from treated setts given that the treatment helps to generate seed yams that are larger than those produced from untreated setts. Larger seeds are likely to have better survival and will also generate larger ware yam tubers. It is also likely that seeds from treated setts will have less pest and diseases. Thus when farmers plant seeds produced from treated setts they are probably planting larger tubers with less pest and disease. Hence the question remains as to whether differences in ware yam production are a reflection of larger seed yams or their lower pest/disease burden or a combination of both? These are questions that probably require a dedicated research programme rather than the use of farmer demonstrations as in this study, but the results would be enlightening.

One other dimension that requires further research is the longevity of the pesticide effect. The results presented here show that the treatment of setts with pesticide in 2013 carried over into ware yam production in 2014, but what if those ware yams were in turn used as mother yams for further production of setts and seed yams? Would the positive effect of the pesticide dip continue to provide benefits at the start of another cycle of seed yam production? It is unlikely, given their nature, that the pesticides (chlorpyrifos and mancozeb) would remain in the tubers in any significant concentration but their effects in terms of reducing the pest/disease load might be persistent. Chlorpyrifos, for example, does decay within plant material and yam setts remain in the soil for 270 days or so before harvest. The extent of this decay within planted yam setts is unknown, but a half-life in humid tropical soil has been

reported to typically vary between seven and 120 days (Chai et al., 2013). Whilst the rate of decline in plant material may be different from that in soil it is likely that by the time of harvest any chlorpyrifos in the sett at the time of planting would have declined significantly. Also, chlorpyrifos is not translocated in plants and hence it is unlikely that the chemical will find its way from the sett to the new tuber. Mancozeb has an even lower soil persistence than chlorpyrifos with a reported field half-life of 1 to 7 days (Doneche et al. 1983). But if the benefits of the pesticide treatment do have a long-lasting effect then maybe it is possible to have two cycles of seed and ware yam production arising from just one application of pesticide and this would clearly have both environmental and economic benefits.

Conclusions

The results from the YIIFSWA demonstrations in 2014 provide a number of insights. Firstly it provides further affirmation for many of the sett-to-seed results presented for 2012 and 2013 in Morse and McNamara (2014). While this may be an incremental conclusion it nonetheless provides further confirmation that the AYMT is a viable approach to quality seed yam production in Nigeria. However, and far more importantly, the results presented here provide the first agronomic evidence obtained under entirely farmer-managed conditions in Africa that seed yams produced via the AYMT can provide significant benefits for ware yam growers in Nigeria. While the positive contribution of planting good quality seed yams has often been mentioned by farmers this is the first time that the statements have been supported by agronomic data obtained in conditions that closely match what farmers do in terms of ware yam production. The results also provide some pointers with regard to future research on the longevity of the benefits through new cycles of sett-seed-ware yam production.

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Table 1. Number and types of AYMT demonstration plots established as part of the YIIFSWA project in 2014

(a) Core demonstrations		Number of demonstrations managed by:	
	Total number of demonstrations	Men	Women
Idah	30	26	4
Amoke	14	9	5
Agagbe	1		1
Illushi	1	1	
FCT	51		
(b) Entrepreneur sites			
	Total	Men	Women
Idah	20	15	5
Amoke	12	6	6
(c) Seed to ware yam plots			
	Total	Men	Women
Idah	30	27	3
Total number of demonstrations	159		

Table 2. Number of seed yams planted in the seed-to-ware yam demonstrations of 2014.

Site number	Variety	Number seeds planted	
		Untreated	Treated
1	Ekpe	100	100
2	Opoko	100	200
3	Opoko	100	150
4	Ekpe	100	180
5	Ekpe	100	300
6	Ekpe	100	360
7	Ekpe	100	200
8	Ekpe	100	400
9	Ekpe	150	600
10	Ekpe	100	200
11	Ekpe	150	450
12	Ekpe	150	600
13	Ekpe	100	250
14	Opoko	90	300
15	Ekpe	300	600
16	Opoko	100	200
17	Opoko	100	200
18	Opoko	200	721
19	Opoko	150	114
20	Ekpe	120	180
21	Ekpe	100	150
22	Ekpe	60	120
23	Opoko	100	320
24	Ekpe	100	117
25	Ekpe	300	575
26	Opoko	100	200
27	Ekpe	100	304
28	Ekpe	100	162
29	Ekpe	100	135
30	Ekpe	100	117

Figure 1. The cycle from setts to seed yam and ware yam.

Figure 2. Average germination rate (%) for untreated and treated setts along with the average weights of seed yam tubers (kg/tuber) harvested from untreated and treated setts. Bars ($\pm$ standard error) with the lighter shading are for seed yams produced from untreated setts and the darker shading is for seed yams produced from treated setts.

Figure 3. Average number of seed yam tubers and average tuber weight (kg/tuber) per sett planted and germinated. Bars ($\pm$ standard error) with the lighter shading are for seed yams produced from untreated setts and the darker shading is for seed yams produced from treated setts.

Figure 4. Average germination rate (%) and harvested tuber weights (kg/tuber) for ware yams produced by seed yams grown from untreated and treated setts. Bars ($\pm$ standard error) with the lighter shading are for ware yams produced from seed yams grown from untreated setts and the darker shading is for ware yams grown from seed yams produced from treated setts.

Figure 5. Average number of ware yam tubers and average ware yam tuber weight (kg/tuber) per seed yam planted and germinated. Bars ($\pm$ standard error) with the lighter shading are for ware yams produced from seed yams generated from untreated setts and the darker shading is for ware yams grown from seed yams generated from treated setts.